

## The Stacked Ring Shell Structure of Atomic Nuclei

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### ABSTRACT

This article proposes a stacked ring shell model that can represent the structure of atomic nuclei, and provides the nuclear structure arrangements of 349 isotopes of 112 elements in the periodic table.

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Existence often depends on the stability of the structure, and complex phenomena often contain patterns. The first and second items above imply a strong repulsion between protons, for example,  $2\text{He}$  cannot exist; There must be neutron between protons to reduce this repulsive effect, such as the presence of  $3\text{He}$ . The third, fourth, and fifth items mentioned above imply differences in the parity symmetry of atomic numbers, as well as differences in structural stability. Therefore, the more stable the structure of the isotope with the highest abundance of an element, the fewer stable isotopes of that element. Obviously, the structure of elements with odd atomic numbers is usually more stable than those with even numbers, such as  $9\text{-F}$  and  $11\text{-Na}$ ,  $13\text{-Al}$ ,  $15\text{-P}$ ,  $21\text{-Sc}$ ,  $25\text{-Mn}$ ,  $27\text{-Co}$ ,  $33\text{-As}$ ,  $39\text{-Y}$ ,  $45\text{-Rh}$ ,  $55\text{-Cs}$ ,  $59\text{-Pr}$ ,  $65\text{-Tb}$ ,  $67\text{-Ho}$ ,  $69\text{-Tm}$ ,  $79\text{-Au}$ ,  $83\text{-Bi}$ ,  $89\text{-Ac}$ , and  $91\text{-Pa}$ , they all have only one stable isotope. By comparison, except for element 4 beryllium, all elements with even atomic numbers before Pu 94 have two or more stable isotopes.

People have proposed various nuclear structure models, among which the shell model (SM) composed of proton-neutron pairs has been commonly used for calculations, but there is no model that can fully explain the above facts [1,2]. This article proposes that different rings are first formed by proton-neutron pairs ( $p-n$ ), and then these rings are stacked to form a stacked closed shell layer. Here, we use different numbers with circles to represent these rings composed of proton-neutron pairs. The number  $N_{p-n}$  representing the number of proton-neutron pairs that make up these rings is listed in Table 1. According to the size of the ring, the number of neutrons  $N_{\odot}$  that can be accommodated in the center of different rings is also listed.

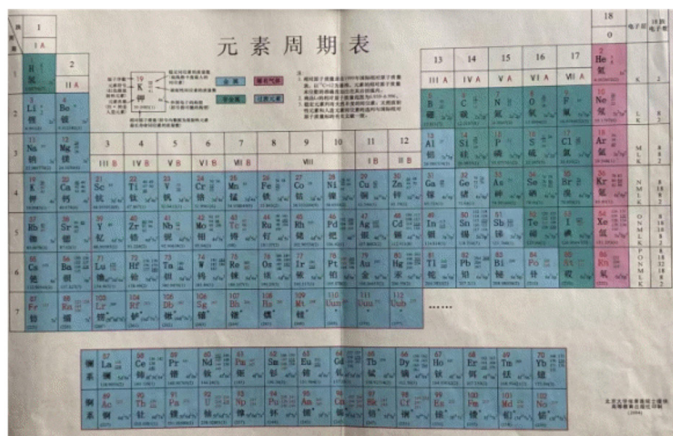
**Table 1: Composition of Annular Structure**

Ring name	②	④	①	③	⑤	⑦	⑨	⑪	⑬
$N_{p-n}$	2	4	1	3	5	7	9	11	13
$N_{\odot}$	0	1	0	0~1	1~3	2~5	3~7	4~9	5~11
apply	single ring		Can form stacked rings						

In Table 1, the ring name ① represents a pair of protons and neutrons; ② A ring formed by two pairs of proton-neutron pairs, specifically referring to  $4\text{He}$  or alpha particles; ③ A ring formed by 3 pairs of proton-neutron pairs, with a center that can accommodate 0 to 1 neutron; ④ A ring formed by 4 pairs of proton-neutron pairs, with one neutron added specifically to represent the case of  $9\text{Be}$ . ⑤ A ring formed by 5 proton-neutron pairs, with a center that can accommodate 1-3 neutrons; ⑦ A ring formed by 7 proton-neutron pairs, with a center that can accommodate 2-5 neutrons; ... .



**Table 3: Periodic Table of Elements**



By the stacked ring shell structures listed in Table 2, it can be seen that the two poles formed by ①③ and ③① are more stable than the two poles formed by ③. For example, among lighter elements, the 8th element oxygen, the 11th element sodium, the 13th element aluminum, the 14th element silicon, the 17th element chlorine, the 19th element potassium, the 20th element calcium, and the 26th element iron, all belong to the former group, which are the most abundant elements on Earth. Especially for some elements with even atomic numbers, due to the symmetry on both sides of the equatorial gap, adding a ③ ring in one polar region will inevitably add a ③ ring in the other polar region. Causing the atomic number of such stable elements to increase by 6, forming an arithmetic sequence: 2-He, 8-O, 14-Si, 20-Ca, 26-Fe. The five elements of this small sequence, due to their similar structural stability, make the last four of them enter the group of the most abundant elements on Earth.

The shell structure of some elements is not necessarily unique. For example, the structure of atomic nucleus of calcium in Table 2-1 has two configurations, which are now explained as follows:

$$20. \textcircled{1}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{1} \rightleftharpoons \textcircled{5}\textcircled{5}\textcircled{5}\textcircled{5}$$

40		
42	1 1	
43	1 1 1	
44	1 1 1 1	↔
	1 1 1 1	
46	1 2 2 1	
48	2 2 2 2	

The "(20)" at the beginning of the first line represents element Ca. The left side of the equilibrium equation indicates that it is composed of two ① rings and six ③ rings overlapping. When the center of all ③ rings does not contain neutrons, it is the most stable ground state, with a mass of 40 and an underline indicating the most abundant isotope. The six vertical numbers 40, 42, 43, 44, 46, and 48 respectively represent the six isotopes of calcium:

40Ca, 42Ca, 43Ca, 44Ca, 46Ca, and 48Ca. The small number below a ring represents the number of neutrons held at the center of the ring.

The right side of the equilibrium equation indicates that the calcium nucleus also has a resonance excited state configuration composed of four overlapping ⑤ rings. 44Ca is prone to resonance conversion between two configurations; 46Ca distributes two neutrons in each of the two ⑤ rings in the middle, and one neutron in each of the ⑤ rings at both ends. 48Ca distributes 2 neutrons in each of the 4 ⑤ rings. Because the hollow ⑤ ring increases the internal repulsion energy, the four ⑤ rings on the right side of the equilibrium equation cannot become the ground state configuration of the calcium nucleus, that is, the most abundant 40Ca will not adopt the configuration on the right side. The center of one ③ ring cannot accommodate two neutrons, so 46Ca and 48Ca cannot adopt the left configuration.

Another example similar to calcium is the 18th element Ar, which has three stable isotopes: 36Ar, 38Ar, and 40Ar. It also has the following two configurations of resonant states (only one configuration is shown in Table 2-1)

$$(18) \textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3} \rightleftharpoons \textcircled{1}\textcircled{3}\textcircled{5}\textcircled{5}\textcircled{3}\textcircled{1}$$

36		
38	1 1	↔
	1 1	
40	1 1 1 1	↔
	2 2	

The left side of the above equilibrium equation is composed of six overlapping ③ rings, which have higher energy than the ①③ and ③① ends of calcium. On the right side of the equilibrium equation of Ar above, there are ①③ and ③① ends, which have lower energy than the four ⑤ rings on the right side of calcium. Therefore, regardless of the resonance configuration used, the energy of the isotope 40Ar of element 18 argon is lower than that of 36Ar. As a result, 40Ar, which is filled with four neutrons, is the most abundant isotope; However, 40Ca, which is completely unfilled with neutrons, is the lowest energy isotope with the highest abundance. Therefore. Calcium and argon can form a clear contrast.

Another interesting example is the 26th iron element, which also has the following two configurations (only one is shown in Table 2).

$$(26) \textcircled{1}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{3}\textcircled{1} \rightleftharpoons \textcircled{3}\textcircled{5}\textcircled{5}\textcircled{5}\textcircled{3}$$

54	1 1	
56	1 1 1 1	↔
	1 1 1 1	
57	1 1 1 1 1	↔
	1 2 1 1	
58	1 1 1 1 1 1	↔
	1 2 2 1	

Although the left configuration in the equilibrium equation of the iron element mentioned above contains ends ①③ and ③①, the long overlap of eight of the ③ rings results in an increase in the energy of the entire empty ring state. Therefore,  $^{52}\text{Fe}$  was not able to enter the ranks of stable isotopes of iron. The energy level difference between the left and right structural formulas in the equilibrium equation of iron decreases, and the nuclei of  $^{56}\text{Fe}$ ,  $^{57}\text{Fe}$ , and  $^{58}\text{Fe}$  isotopes can undergo resonance transformation between the two configurations. It can also be seen from this that the five arithmetic sequences with atomic numbers 2, 8, 14, 20, and 26 discussed above end after iron.

From the above example, it can be seen that as the atomic number increases, there are more and more stacked rings, and the central cavity of rings also becomes larger, accommodating more and more neutrons. Especially for elements with  $Z > 20$ , two structural factors should be taken into account. Firstly, the number of overlapping ③ rings has exceeded 6, and this entire hollow core configuration is no longer the lowest energy. Secondly, an increasing number of larger odd numbered rings are appearing, such as the ⑤ ring, ⑦ ring, ⑨ ring, ⑪ ring, and ⑬ ring. These two factors cause the elements after calcium to enter the fast lane of the increasing neutron number with an increase in atomic number. This precisely explains the sixth item fact mentioned above.

In summary, the stacked ring shell model proposed in this article reveals the mysteries and laws of complex atomic nuclear structures, consistent with well-known facts.

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#### Author contributions

Xiao En Wang, Deng Guo Wang and Yin Bo Wang wrote the paper.

#### Competing interests

The authors declare no competing interest.

#### Data Availability Statement:

There is no availability data other than this manuscript.

#### References

1. Orce JN, Ngwetsheni C, Brown A (2023) Global trends of the electric dipole polarizability from shell-model calculations. *Physical review C* 108: 044309.
2. Orce JN (2025) Subshell gaps and onsets of collectivity from proton and neutron pairing gap correlations. *Atomic Data and Nuclear Data Tables* 162: 101699.
3. Chemistry Textbook Writing Group for Vocational and Technical Colleges, Inorganic Chemistry Experiment. Higher Education Press, Beijing. Second edition, 2002.

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